STRENGTH OF MATERIALS
Mechanical Properties of Materials

Objective

The goal of this exercise is to determine and compare the following tensile mechanical properties of 1040 steel and 2024 T4 Aluminum:

a. Modulus of Elasticity
b. Yield Strength (Upper and lower where applicable)
c. Ultimate Strength
d. Percent Elongation
e. Percent Reduction of Area
f. Specimen Toughness
g. Material Toughness

Theory

The satisfactory performance of a structure is frequently determined by the amount of deformation and load which can be permitted. It is often necessary to relate the loads on a structure to the deflection the loads will produce. Such information can be obtained by plotting diagrams showing loads and deflections for each member and type of loading in a structure, but such diagrams will vary with the dimensions of the members. A more useful diagram is one showing the relation between stress and strain.

A testing machine is used to strain the specimen and to measure the load required to produce the strain. A slow axial tensile load is applied at room temperature to a standard ASTM specimen. The load values and corresponding deformations are recorded as raw data. These values are converted to stress and strain respectively and plotted as a stress-strain diagram. The mechanical properties listed below are determined from this curve.

1. Modulus of Elasticity (E psi): the slope of the straight line portion of the stress-strain diagram.

2. Yield strength, σ_{ys} (psi):

   a. Materials with a distinct proportional limit:

$$\sigma_{ys} = \frac{\text{load at proportional limit}}{\text{initial cross-sectional area}} \tag{1}$$

If a drop in load occurs at the proportional limit, the lower yield strength is used for design purpose. This yield stress is generally found in structural steels and iron and in glasses and ceramics.

b. Materials without a distinct proportional limit:

$$\sigma_{y0.2\%} = \frac{\text{load at strain offset}}{\text{initial cross-sectional area}} \tag{2}$$

The load at strain offset is obtained by fitting a line to the linear portion of the stress strain curve. This line is then offset in strain by shifting this line by 0.002 in/in to the right. The load at which this line intersects with the stress-strain curve is the "load at strain offset" used to calculate yield stress. This yield stress is called a 0.2% offset yield stress. This method of determining yield stress is used for structural aluminum, magnesium, titanium and most other materials including polymers.

3. Ultimate tensile strength, σ_{ult} (psi)::

$$\sigma_{ult} = \frac{\text{maximum load}}{\text{initial cross-sectional area}} \tag{3}$$

4. Percent Elongation %:

$$\%\ \text{Elongation} = (\text{Strain at Fracture}) \times 100\% \tag{4}$$

5. Percent Reduction of Area (%):

$$\%\ \text{Reduction of Area} = \frac{\text{Initial Area - Final Area}}{\text{Initial Area}} \times 100\% \tag{5}$$

6. The area under the load displacement curve (in-lbs) is the energy required to fracture the specimen. This area can be approximated by counting squares on the graph paper or by a simple numerical integration using the trapezoidal rule on the digital data file.

7. The area under the stress-strain plot (in.-lb/in^3) to failure is the energy per amount material volume required to break the specimen. This area can be evaluated from the from the digital data file of the stress-strain curve using a numerical integration process. Notice that this energy/unit volume can be obtained by dividing the fracture energy of item (6) above by the initial volume (A_oL_o) of the test section of the specimen.

Procedure:

Both the aluminum and steel specimens to be used in the exercise are standard 0.505 inch diameter specimens. Each specimen will be mounted in the Instron Universal testing machine which is used to apply a slow, uniform extension. An extensometer having a two inch gage length will be mounted on the specimen to measure the corresponding gage length deformation. Output from both the Universal testing machine (load applied to specimen) and the extensometer (specimen deformation) is fed directly to a PC which uses an analog to digital conversion module to take readings of the transducer voltages corresponding to the test machine load and the extensometer elongation. The input voltages are converted to load and elongation using calibration factors input to the computer, and the results are displayed on the CRT screen and stored on the computer disk.

An X-Y recorder is also used to draw an analog load versus elongation plot on standard graph paper.

Each student is required to use QUATTRO or EXCEL to import the data file corresponding to each test. See instructions below on importing data into QUATTRO (or EXCEL). Use spreadsheet functions to obtain stress and strain results. Plots of stress versus strain are then to be made using spreadsheet graphic capabilities. Each specimen will be tested using the following process:

Measure the initial diameter of the specimen and mount it in the testing machine.

Install the extensometer on the specimen taking care to set the initial gage length to 2.0 inches, and to install the gage in line with the specimen axis.

Load a fresh sheet of plot paper in the X-Y recorder.

Calibrate and select appropriate scales/ranges on the Universal testing machine and X-Y plotter. The instructor will provide assistance as necessary.

Load each specimen to rupture.

Measure final diameter of specimen.

Copy the data file from the PC hard drive to the student floppy drive or download the data from the specified web site.

QUATTRO or EXCEL will then be used by each student to evaluate the stress and strain data, and for preparing stress-strain plots. X axis magnification is necessary to obtain an accurate yield stress for the Aluminum specimen.

The stress-strain diagrams will be used to find the appropriate tensile mechanical properties.

The modulus of elasticity should be obtained using a least squares best fit procedure, using the appropriate data from the spreadsheet.

Importing Data into QUATTRO:

1. Under Tools
2. Data Tools
3. Quick Columns...
4. Set the SOURCE to FILE
5. Enter the filename and the selected Options
6. Set the data Type to DELIMITED

7. Under Delimited, make sure the "Comma" button is filled
8. Select "OK"
9. Select PARSE.

Entering Data into EXCEL:

1. Under Files, choose Open,
2. Under "Files of type" choose All files (*.*),
3. Locate the desired *.dat file under c:\tensile,
4. Double click to open the file.
5. Cutting and pasting can be used to move the data to a summary spreadsheet.

Report:

The laboratory report should include plots of the load displacement records and the stress-strain curve for both specimens. Specimen properties and material properties should be labeled on these figures. Also include the results of all calculations and sample calculations where applicable. Use the laboratory format assigned by your instructor.

Summary of Results:

	1040 Steel	2024 T4 Aluminum
Slope of linear fit		
Y-Intercept		
Coefficient of Fit		
Modulus of Elasticity (psi)		
Yield Strength (psi)		
Ultimate Strength (psi)		
% Elongation		
% Reduction of Area		
Specimen Toughness (in-lbs)		
Material Toughness (in-lbs/in^3)		
Attach plots of Stress vs. Strain for each specimen		

revised by M. Koul 1/02